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Heat Transport in Groundwater Systems--Laboratory Model

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- Full Text

Solar energy is a possible alternate energy source for space heating. A method of economic long term solar energy storage is needed. Researchers have proposed storing solar energy by heating water using solar collectors and injecting the hot water into groundwater aquifers for long term energy storage. Of paramount importance to the success of such a system is the quality and the behavior of the aquifer used for hot water storage. In general, the problem is to obtain an accurate prediction of the response of an aquifer system and its basic components to the operation of a system of injection and pumping wells which are transporting water at a notably different temperature than the natural groundwater.

The injection of hot water into a groundwater storage system will have a pronounced effect on the specific storage and mass flow within the aquifer. These effects will result from differences in viscosity, density, specific heat, and thermal conductivity between the injected water and the natural groundwater. A complex system of energy and mass transport will result, making analytical solutions unattainable or very complex.

The objective of this study was to develop a numerical simulation which would predict the pressure and temperature of water in a groundwater system at any time in response to the pumping and injecting of hot and cold water. A numerical model was developed in which the groundwater flow equation and the energy transport equation are solved simultaneously using a finite difference approximation for the time derivative and three-dimensional Galerkin-finite element approximations for the space derivatives.

The use of a strict Galerkin approach led to unacceptable solution oscillations in sharp temperature front problems (i.e., problems where the temperature changes quickly over a small distance or time). Several techniques were tried in an attempt to correct the problem. Reduction of element and time step size proved ineffective in eliminating the

sharp temperature front oscillation problem. An upstream weighting scheme corrected the oscillation problem, but resulted in an unacceptable smear of the sharp temperature front. A mass lumping scheme resulted in the best solution to sharp temperature front problems. The mass lumping scheme yielded solutions without the oscillation problem and with less smear than the upstream weighting scheme.

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